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(54) **A portable electric tool**

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Description

[0001] This invention relates to a portable electric tool using AC motor or a brushless DC (BLDC) motor.

BACKGROUND

[0002] It is well known that modern manufacturing techniques deploy a number of portable tools to tackle the repetitive jobs that are encountered in the shop floor of the industry. Tools like drills, grinders, shears, nibblers, screw drivers, nut runners and impact wrenches find extensive use in large fabrication shops, tool rooms, fettling shops and assembly lines. In addition such tools also find large usage as do-it-yourself (DIY) tools in the hands of the individuals in domestic applications. Also such portable tools are widely used in mines particularly in the form of drills. The main requirements of such tools are portability, ease of handling and usage, safety, high efficiency and maximum power output. The manufacturer always aims to achieve the maximum power-to-weight ratio in such tools. Nowadays the energy consumed by such tools is also becoming an important criterion for selection.

[0003] Presently available range of portable tools can be broadly classified into three types. They are given as under:

- AC/DC Universal Motor Based Electric Tools
- Pneumatic Tools
- Conventional High Frequency Tools

[0004] The first type mentioned above uses a universal electric motor. These motors are essentially series-wound DC Commutator motors that have been specially designed to operate in AC as well. The stator core is invariably laminated to reduce losses. A well-designed universal motor is cheap, of lightweight and can operate directly from the AC mains. The fact that it does not require a special power source is a major reason for its widespread use. This type of tool finds extensive use in DIY applications and small shops where one-off usage is normal.

[0005] The Universal Electric tools suffer from certain disadvantages in that

- The Commutator/Carbon Brush-gear is a perennial source of problem leading to reduced reliability and increased maintenance
- In these motors, the speed drop from no-load to full-load is very high, often of the order of 2:1. Excessive overloads can cause stalling of the motor, leading to armature burnout.
- As the motor operates on mains supply, it has to be designed with double-insulation or reinforced insulation with proper earthing, to achieve the required safety levels.
- It is difficult to make these tools flameproof for use in mines and other hazardous areas.

[0006] Due to these reasons the Universal Electric tools are generally not preferred for heavy duty, continuous loads and in arduous working environment.

[0007] The second type, viz., the Pneumatic Tools was essentially developed to overcome some of the problems associated with the Universal Electric tools. The pneumatic tool operates from high-pressure compressed air by means of a simple drive called vane motor. A rotor with vanes supported on bearings runs inside a housing due to the passage of the compressed air and high speeds are achieved. A reduction gearbox is used to reduce the speed and increase the torque. While the pneumatic tool is versatile and absolutely safe, they also suffer from certain disadvantages, as detailed below:

- Like Universal Tools, the Pneumatic Tools also exhibit steep fall in speed on increasing loads and a tendency for stalling.
- They require a centralized compressed-air line, which is expensive and difficult to maintain.
- As the pneumatic motor operates best on dry air, free from dust and moisture, each of the tools must be equipped with a FRL (Filter-Regulator-Lubricator) unit.
- Over its life, due to continuous ware and tare the Pneumatic Tool requires regular maintenance, as also the air line.
- Even with a well-designed compressor and air line, the pneumatic system is very inefficient. The overall efficiency of the system, as measured by the ratio of the power available at the output shaft of the tool to the input of the motor of the compressor, is very poor compared to the electric system.
- The overall systems costs are quite high.

[0008] It is mainly to obviate the drawbacks of the Universal Electric and Pneumatic Tools that the High Frequency (HF) Tools were developed. The HF tools employ a three-phase AC induction motor as the prime mover. This motor, with its virtually indestructible diecast rotor, is very rugged and reliable. Also the motor exhibits a speed-torque characteristic that is totally different from the Universal and Pneumatic tools. The speed of the induction motor drops very little on the application of the full load and this results in higher productivity and it is virtually impossible to stall this type of motor by hand.

[0009] It is also a known fact that the speed of the induction motor is proportional to the frequency and at the nominal power frequency of 50 or 60 Hz that is generally available, the maximum speed that can be achieved from an induction motor is only about 3000/3600 rpm. As the size of an electric motor for a given output is inversely proportional to its operating speed, the size of the motor for a particular output will be higher than that of the universal motor with its high operating speeds. Thus an induction motor operating from the convention-

al line frequency will be heavy and portability can be achieved only by increasing the frequency of operation of the induction motor.

[0010] This type of HF tools made their appearance in the market a few decades ago. As the tools required higher frequency, there was a centralized frequency converter to convert the 50 or 60 Hz, three-phase supply to 200/300/400 Hz three-phase supply. There were separate running power lines to distribute the HF supply to various places in the shop floor. Non-standard electrical accessories in the form of plugs and sockets were used to differentiate them with the standard parts meant for 50/60 Hz usage.

[0011] While the HF system was advantageous from the point of view of reliability, productivity and operational efficiency, they suffered in terms of high cost of installation of the centralized HF converter and distribution system. They were virtually excluded in the one-off usage or DIY applications due the high costs of the high frequency converter and the distribution network. They found their use only in cases where a battery of such tools is applied. Even here, there was the disadvantage that the HF converter had to be switched ON even when only one or a few tools were needed to be operated.

[0012] Also both the HF and the Pneumatic systems suffer from the handicap that they are not truly portable in the sense that a separate air line or HF line is required for operation of them. And they certainly ruled themselves out in the case of DIY or typical one-off usage in smaller shops.

[0013] Prior art document GB-A-1120980 discloses a portable electic tool powered by a high frequency motor which can be directly connected to the mains.

[0014] Document DE-A-19 631 517 also discloses such an electric tool with an incorporated electronic command.

[0015] The object of this invention is to obviate the above drawbacks by packaging the electronic circuit of a frequency cum phase inverter, as described in my Indian co-pending application no. 867/Mas/99 for an AC motor or a brushless DC (BLDC) motor within the tool itself.

[0016] The second object of the invention is to provide heat sink for the power transistors of the PWM bridge inverter of a high frequency cum phase inverter in the tool.

[0017] The third object of the invention is to accelerate the motor in a soft-start mode limiting the in-rush current during starting.

[0018] To achieve the said objectives, this invention provides a portable electric tool comprising:

- a casing for a motor,
- a non-drive end cover having a bearing at its center for the said motor,
- a heat sink provided either integrally or separately on the said covers,
- PWM bridge inverter consisting of power transistors with corresponding gates, the output of the said PWM bridge inverter is connected to the said motor,
- the said power transistors terminals are connected to a printed circuit board (PB) and are mounted on the said heat sink
- the controller unit having a software programme of short code length and the driver TC for driving the said gates are connected to another printed circuit board (CB),
- the said two boards (PB & CB) are inter-connected for determining the timing sequences for generating the signals for switching ON / OFF the gates of the power transistors of the said PWM bridge inverter in order to produce variable voltage variable frequency (VVVF), sinusoidal wave forms for controlling the speed of the said motor using space vector pulse width modulation (SVPWM) or sinusoidal pulse width modulation (SPWM) technique, and are mounted through mounting means to the said heat sink,
- a cooling means mounted on the shaft of the said motor to first cool the electronics of PB & CB mounted on the heat sink and thereafter cool the stator of the motor,
- an input rectifier and the filter capacitors are connected to PWM bridge inverter, an auxiliary power supply, which provides the power supply to the controller unit and the driver IC are housed in the handle of the tool.

[0019] The said motor is an AC motor or brushless DC motor. The said AC motor is a single-phase motor or a three phase motor or a poly-phase motor. The said AC motor is an induction, reluctance or synchronous motor. The brushless DC (BLDC) motor is in two or three phases with two or three pairs of winding.

[0020] The PWM bridge inverter (single phase inverter) consists of at least 4 power transistors with corresponding gates in case a single-phase motor is connected at its output.

[0021] The said software programme provides not more than four switching configurations of the said inverter bridge to produce variable voltage variable frequency (VVVF) sinusoidal voltage wave form for controlling the speed of the said single-phase motor using space vector width modulation (SVPWM) or sinusoidal pulse width modulation (SPWM) technique.

[0022] The PWM bridge inverter (three-phase inverter) consists of at least six power transistors with corresponding gates and the AC motor connected to the output of said PWM bridge inverter is a three-phase motor or brushless DC (BLDC) motor with three pairs of windings (three-phases).

[0023] The said software programme provides not more than eight switching configurations of the said inverter bridge to produce variable voltage variable frequency (VVVF) sinusoidal voltage wave form for controlling the speed of the said three phase motor using

space vector width modulation (SVPWM) or sinusoidal pulse width modulation (SPWM) technique.

[0024] Two single phase PWM bridges totaling eight power transistors are provided for BLDC motor with two pairs of winding (two-phase motor), the output of each of these two bridges is connected to the two winding pairs such that the output of second winding is delayed by 90° from the first one.

[0025] The said software programme manipulates switching configurations of the said inverter bridge to produce variable voltage variable frequency (VVVF) sinusoidal voltage wave form for controlling the speed of the said motor using space vector width modulation (SVPWM) or sinusoidal pulse width modulation (SPWM) technique.

[0026] The mounting means are the mounting screws and the means for cooling is an induced draft fan.

[0027] A higher grade silicon steel of reduced thickness is used as core in the motor to reduce the core-losses of the said motor.

[0028] The ON / OFF switch of the tool is also incorporated in the handle.

[0029] The output shaft of the said motor is connected to the gearbox, when required.

[0030] The controller is a micro-controller with the associated processor, ROM, RAM and the input / output (I/O ports) having said software programme in ROM to produce timing signals through the output port to the said gates through the driver IC.

[0031] The said software programme includes soft-start means.

[0032] The said controller unit provides a multi-speed capability to the said motor, if desired.

[0033] The said power transistors in the PWM bridge inverter are of MOSFET (metal oxide semi-conductor field effect transistor) or IGBT (insulated gate bi-polar transistor), type to make the gate driver circuitry simple.

[0034] The heat sink for the power transistors and the non-drive side end cover of the motor have been integrated to achieve optimum utilization of space.

[0035] Thermal over-load protection means is provided for the motor windings.

[0036] The over-current protection means are provided for the said PWM bridge inverter.

[0037] The short code length of the programme is from 100-1000 bytes, preferably 200-400 bytes depending upon the number of speed steps required.

[0038] The said software programme in the micro-controller is such that it obtains the maximum utilization of the said input DC voltage to the inverter by the implementation of SVPWM technique.

[0039] The said software programme generates a symmetric pattern of timing signals thereby producing variable voltage variable frequency (VVVF) single phase or polyphase sinusoidal wave forms with the least harmonic content.

[0040] The said software program also includes means to generate dead band in the switching signals to ensure that at no point of time any 2 transistors in the same leg of PWM bridge inverter are conducting simultaneously.

[0041] The said software program further includes means to obtain the set speed of the said motor from the operator console

[0042] The said auxiliary power supply means generates the 5V, 15V DC required for powering the micro-controller and the driver IC respectively.

[0043] The controller, driver IC and the auxiliary power supply are implemented in an ASIC.

[0044] The controller ASIC has means to interface with an external memory chip, if required.

[0045] A digital sign wave synthesizer is provided, which generates in real time, a set of single phase or polyphase wave forms as per the Space Vector Pulse Width Modulation (SVPWM) technique.

[0046] The controller unit and the passive components are implemented in a hybrid IC

[0047] The invention will now be described with reference to the accompanying drawings.

[0048] Figs. 1, 2 and 3 show the general assembly arrangement of three types and sizes of the tools, namely, HF Angle Grinder, HF Drill and HF Die Polisher respectively incorporating a frequency cum phase inverter inside the tool itself, according to this invention. The layout of the electrical, electronic circuitry of micro-controller, PWM bridge inverter and mechanical systems are shown therein.

[0049] In Fig. 4 shows the block diagram of the electronic circuitry of the frequency cum phase converter consisting of the rectifier-filter (1), the three-phase PWM Bridge Inverter (2), the Gate Driver IC (4), the Motor (3), the Micro-controller (5) and the Auxiliary Power Supply (6) for the processor and the gate driver IC.

[0050] Fig. 5a shows PWM single phase bridge inverter consisting of 4 power transistors with corresponding gates for a single phase induction motor.

[0051] Fig. 5b illustrates in greater detail the six power transistors, three-phase PWM bridge Inverter. R, Y and B are the three phase outputs, Q1 - Q6 are the power transistors and G1 - G6 are the six gates of the transistors.

[0052] Fig. 6a illustrates the four possible switching combinations of the four power transistors of the single phase inverter bridge.

[0053] Fig. 6b illustrates the eight possible switching combinations of the six power transistors, three-phase inverter bridge. The ON or OFF state of the bottom side power device of the bridge is considered to denote the state of the bridge. The eight possible combinations are V_0 - V_7. V_0 and V_7 represent the bridge in OFF or non-conducting condition in that either all the three bottom or the top power devices are in ON State. In all the other six states V_1 - V_6, the bridge is in ON State. One or two of the topside devices and two or one of the other bottom side devices are in ON State.

[0054] In Fig. 7 the soft-start mechanism is illustrated.

The step by step incrementing of the frequency and speed and the shifting of the maximum torque position is explained therein.

[0055] Fig. 8 shows the variation of the current with speed as the motor is accelerated in the soft-start mode. The inrush current is limited to I_{max} during the entire acceleration period.

[0056] Fig. 9 illustrates the flow-chart for implementation of the software for the micro-controller. The main program for the Start/Stop control and the subroutine for the implementation of the Space Vector PWM technique is shown therein.

[0057] Fig. 10 shows the variations of the weight of the motor and the gearbox with respect to speed. The variation of the complete weight of the tool as a function of the speed is also given.

[0058] Fig. 11 shows the exploded view of the portable high frequency (HF) tool and the positioning and packaging of the various sub-assemblies as indicated therein.

[0059] Referring to drawings, in figures 1, 2 or 3 the general layout of the assembly of tools viz. Angle Grinder, portable Drill and Die Polisher is given. The assembly of the tool is made up of the electronic frequency-cum-phase converter, the stator, diecast rotor, housing, the gearbox and the output shaft. In the die polisher, shown in Fig. 3, since the full high speed of the motor is required at the output shaft, there is no gearbox. There is also a cooling fan fitted to the motor shaft. The fan sucks the cool air from the ambient, first passing it over the heat sink of the power transistors and then passing it over the stator of the motor.

[0060] The packaging of the electronics, viz., the rectifier-filter (1), the printed circuit board (power board) (PB) and the another printed circuit board (controller board) (CB) is done in an innovative manner, as shown in fig. 11. The heat sink (HS) for the power transistors of the inverter bridge and the non-drive side end cover of the motor have been integrated in a novel fashion to achieve optimum utilization of space. The space inside the handle (H) is also utilized well to house the filter capacitors and the auxiliary power supply (6).

[0061] The packaging of the electronic circuitry of the frequency cum phase inverter and layout of various sub-assemblies of the tool is explained at length in fig 11, which is an exploded view of the assembly bringing out the novel features of the assembly. In this view, only the motor (M) and the handle side (H) of the assembly, where the electronic circuitry of the frequency cum phase inverter is packed, is shown. The gear-box side of the tool, where the output shaft of the motor is connected to the gear box and from their to the tool holder is not shown in this figure. The gear-box side of the tool is common for different types. In this figure 11, (B) is the casing that houses the motor stator, (HS) is the non-drive end cover of the motor with heat sink, which houses the bearing in the center and has slots at its periphery. This end cover also acts as a heat sink for the power transistors of the PWM bridge inverter (2) and thus has a dual function. (PB) is the power board in which the power transistors of the PWM bridge inverter (single or three phase inverter) are mounted and the said power transistors are placed on the corresponding slots of the end cover cum heat sink (HS). (CB) is the control board on which the micro-controller and the driver IC are mounted. Item (C) in this figure shows the rectifier - filter and the auxiliary power supply (6) and these are housed inside the handle (H). The two boards (PB) and (CB) are interconnected and are mounted through the mounting screws (S) to the heat sink (HS). The ON/OFF switch of the tool is also incorporated in the handle (H). The heat sink for the power transistors and the non-drive end cover of the motor have been integrated to achieve optimum utilization of space. Further, the space inside the handle (H) is also utilized to house the rectifier - filter and the auxiliary power supply.

[0062] It is well known that the weight of an induction motor is inversely proportional to its speed of operation. Thus to achieve a high power/weight ratio, it is necessary to increase the frequency of the motor input voltage. However the tip or peripheral speeds of the tool like the drill-bit or the grinding wheel is limited and higher sized tools have to operate at correspondingly lower speeds. Thus there is a need for interposing a gearbox between the motor and the tool and this adds to the weight of the tool itself.

[0063] In Fig. 10 the effects of the speed on the weight of both the motor and the gearbox are given. The weight of the motor decreases hyperbolically with the increase in frequency (or speed) while that of the gearbox increases linearly with frequency. The resultant total weight of the tool thus exhibits a trough near 200 - 400 Hz. And this is generally the range in which the HF motors for power tools are designed and operated.

[0064] The core loss of the motor increases with frequency and to reduce the same it is necessary to use higher-grade silicon steel of reduced thickness. But the weight of the motor itself reduces, thereby resulting in cost reduction. Thus there is a trade off between the cost and efficiency of the motor.

[0065] In fig. 4 the frequency-cum-phase converter consists of rectifier-filter (1), the six-power transistors Inverter Bridge (2) (three phase inverter), the micro-controller (5) for generation of the PWM signals through driver IC (4) and the auxiliary power supply (6). The power transistors are of MOSFET (Metal Oxide Semiconductor Field Effect Transistor) or IGBT (insulated gate bi-polar transistor) type. Since the gate of the transistor is insulated from the other two terminals, source and drain, the design of the gate driver circuitry is made simple. The power transistors are mounted on power board (PB)

[0066] The three phase Inverter Bridge is explained in greater detail in Fig. 5(b). Q1 - Q6 are the six MOSFETs and G1 - G6 are the corresponding gates. A high signal at the gate turns the transistor ON and a low sig-

nal turns it OFF. The switching signals to generate a sinusoidal, three-phase wave are given by the controller as per the logic of the algorithm. R, Y & B are three-phase outputs, which are connected to the stator windings of the motor.

[0067] A gate driver IC (4) is used to drive the gates of the six MOSFETs. The IC provides the right signals for the three lower side transistors Q2, Q4 & Q6 and the signals with the required offset voltages for the three high side transistors Q1, Q3 & Q5. The micro-controller (5) gives the required input signals to this IC (4). The controller also ensures that at no time any or all of the three complementary pairs of transistors Q1/Q2, Q3/Q4 or Q5/Q6 are simultaneously switched ON, lest the DC bus gets short-circuited. The three tools shown in Figs. 1, 2, and 3 have ratings of the inverter varying between 300 W to 1800 W. The input supply in all these cases is 240 V, 50 Hz, Single-phase.

[0068] The controller unit (5) is a microprocessor based one with the associated CPU (Central Processing Unit), ROM (Read Only Memory), RAM (Random Access Memory) and I/O (Input/Output) ports. The main job of the controller is to generate switching signals to the six gates G1 - G6, of the bridge in a cyclic manner determined by the SVPWM algorithm. This algorithm has been implemented in a novel way and occupies only about 200 bytes long code.

[0069] The principle of the SVPWM method of digital synthesis of the three-phase sinusoidal waveform is explained in T.G. Habetler, 'A Space Vector Based Rectifier Regulator For AC/DC Converters', IEEE trans.power electronics, vol VIII, no. 1, pp 30-36, 1993. The same is explained briefly in the following manner. There are basically eight basic safe switching combinations of the Inverter Bridge (three phase inverter, as shown in figure 6b). In two of them, either all the top or the bottom transistors are ON and their complementary bottom/top transistors are in OFF position. Under both these conditions the bridge is not conducting. There are six other possible combinations in which the bridge conducts, when one or two of the topside transistors is ON and their complementary bottom side transistors are in OFF position. It is to be remembered that at no time, any of the complementary pairs must be ON simultaneously.

[0070] Any two of the above switching combinations can represent the sum of the three phase voltages of the stator of the motor at a particular instant. The stator voltage vector is resolved into two of the six possible pairs and the algorithm computes the ON times for each of these two combinations. As this vector moves in time through one cycle, the switching combination and the dwelling times of the corresponding two switching combinations are computed by the algorithm. The switching signals are sent through the output port of the micro-controller to the driver IC and thereon to the gates of the transistors of the Inverter Bridge. This PWM signals repeat at the desired frequency and the program loops continuously. The program checks for the ON/OFF position of the switch by means of an interrupt routine on a regular basis and once an OFF position is sensed, the bridge is shut down.

[0071] There is also an over-current protection for the bridge and whenever this set value is exceeded the bridge is completely shut off by the controller. The controller also ensures that the default position of the bridge is the non-conducting state.

[0072] Another novelty of this invention is the soft-start feature that is provided for in the software. When the tool is switched ON, the controller does not set the voltage and the frequency corresponding to the rated values. Instead it sets the values of both V and f at a lower value and the same are increased in steps as per the rules of the soft-start routine to the rated values. The software takes care of this routine also. This feature can be explained in greater detail with the help of Figs. 7 & 8.

[0073] In Fig. 7 and 8 the soft-start feature with five steps are shown. Fig. 7 shows the Torque Vs Speed curves for the five steps while Fig. 8 illustrates the variation of Current with Speed for the same steps. The inverter and hence the motor is started in step 1 at a low frequency and its corresponding voltage. The starting torque is very high and the starting current is well within the allowed value of I_{max}. As the motor accelerates and the speed reaches the value corresponding to step 2. The current value also decreases. At this point both the voltage and frequency are increased. The maximum or pullout torque point is shifted to the right. The motor sees an increase in accelerating torque and the speed further picks up. The current also increases but is kept within I_{max}. Similar exercise is carried out at points 3, 4 & 5. The curve relating to step 5 is the Torque Vs Speed characteristics of the motor at the rated voltage and frequency and the motor follows this curve from the beginning of step 5 and reaches its rated speed.

[0074] The motor is started at a frequency f_1 and an output voltage V_1 corresponding to this, to keep V_1/f_1 at the desired constant value. The value of f_1 is so chosen as to obtain the maximum torque of the motor at a low value of speed. At this point the current is also much less than the usual high value at starting. As the motor accelerates, the controller changes to another operating point V_2 and f_2. The motor speed further increases, without any abnormal increase of current. This process is repeated through V_3/f_3, V_4/f_4, etc., to the rated voltage V and frequency f. At all these points the V/f is kept constant so that the torque developed by the motor is same at all points. At the same time the inrush current during the acceleration is kept within the desired limits. The repetitive peak current carrying capability of the MOSFETs determines this value. Thus the Inverter Bridge is safe even during direct-on-line starting of the power tool.

[0075] Another feature of the software is that whenever there is a change of ON/OFF State in the vertical legs of the bridge, it ensures that both the transistors are not turned ON simultaneously. For example the program will change the switching sequence from 100101

to 101001 during the course of the routine. 100101 means that the transistors Q1, Q4 & Q6 are ON and the transistors Q2, Q3 & Q5 are OFF. 101001 means that Q1, Q3 & Q6 are ON and Q2, Q4 & Q5 are OFF. During this transition it can be seen that Q4 is switched from ON to OFF and Q3 is switched from OFF to ON. It is to be noted that the transistor Q4 has an inherent turn-off time, i.e., it takes a definite time for the transistor to completely switch off. It is then essential that the other transistor in the same leg, Q3 be not switched ON before Q4 is turned off completely. This means that there has to be a time delay between the switching OFF of Q4 and the switching ON of Q3. This delay, known as the dead-band, is required whenever there is such a transition. During the dead-band both the transistors of a vertical leg of the bridge are OFF together. The software provides for such a dead-band and the designer can vary the same by giving a different value to a variable.

[0076] In Fig. 9 the flow chart for the program is illustrated. As explained earlier the entire code is optimized and occupies only 200 Bytes of the ROM. The processor executes the program residing in the ROM portion of the processor in real-time to generate the gating signals of the Inverter Bridge as per the SVPWM method. During starting the soft-start routine is executed. Once the frequency and voltage of the inverter have reached the rated maximum values, the program with suitable interrupt routines checks for the OFF position of the ON/OFF switch. Whenever it senses the OFF position the controller shuts down the bridge by keeping Q1, Q3 & Q5 or Q2, Q4 & Q6 in ON state. This is also the case when the over-current protection is activated. Otherwise when the program senses the ON position during the interrupt, the program computes the ON time for the two space vectors and the timer registers of the processor is loaded and another interrupt is enabled. The spatial position, θ of the stator voltage vector is incremented, starting from zero and the switching pattern is sent to the output port for onward transmission to the driver IC. When the timer interrupt overflows, θ is incremented by $\Delta\theta$ and the process repeated, till θ reaches 360. At this point the motor switch position is checked for ON/OFF. Unless an OFF is seen, the program repeats after initializing θ. The program loops indefinitely.

[0077] The smoothness of the output sine wave is dependent on and can be varied by changing the value of $\Delta\theta$. This value, decided by the designer, can be input as variable in the routine. As the memory and execution time requirements of the code is very low, the same can be implemented in a low-end micro-controller resulting in cost savings. Variable speed of the power tool can also be achieved by having a multi-speed switch and depending on the position of this switch, the program can read the corresponding voltage and frequency and generate the timer values for the space vectors. The control for such applications, even when multi-speed is required, is generally of open-loop type and hence the coding is quite simple.

[0078] Similar exercise is carried out with PWM bridge inverter (single phase inverter) having four power transistors with four switching configurations, as shown in figures 5a and 6a to provide a multi-speed for a single phase motor. For a single phase motor there are two space vectors and four basic switching combinations. The software programme in the microcontroller calculates the dwelling times for each of these configurations and the corresponding dead band programme is also inserted in the appropriate place like in the case of three-phase circuit.

[0079] A brushless DC (BLDC) motor is similar to poly-phase induction motor in construction except that in the brushless DC motor, the rotor is a permanent magnet in stead of die-cast aluminium. Generally, the BLDC motor come in 2 or 3 phases with 2 or 3 pairs of windings and the switching is done in a similar manner as two or three phase motor. While the three phase version is similar to the one, which has been described above, in the two phase motor there are two single phase bridges totaling eight power transistors. The output of each of these bridges is connected to the two winding pairs. The output of the said winding is delayed by 90° from the first one. When the voltages are applied in a cyclical fashion to the windings as described above, a rotating magnetic field is setup and the permanent magnet rotor follows this field and revolves continuously.

[0080] The motor winding temperature can also be sensed by means of a thermal cutout, which opens, when excess temperatures are encountered in the windings. Thus the motor windings will also be protected. As explained earlier a suitable dead-band can be input to the program as a variable to protect against the short circuit of the DC bus.

[0081] The advantage in this portable tool is that apart from a single speed, one can have variable speed of the motor, if desired.

Claims

1. A portable electric tool comprising:

    - a casing for a motor,
    - a non-drive end cover having a bearing at its center for the said motor,
    - a heat sink provided either integrally or separately on the said covers,
    - PWM bridge inverter consisting of power transistors with corresponding gates, the output of the said PWM bridge inverter is connected to the said motor,
    - the said power transistors terminals are connected to a printed circuit board (PB) and are mounted on the said heat sink
    - the controller unit having a software programme of short code length and the driver TC for driving the said gates are connected to an-

other printed circuit board (CB),

- the said two boards (PB & CB) are inter-connected for determining the timing sequences for generating the signals for switching ON / OFF the gates of the power transistors of the said PWM bridge inverter in order to produce variable voltage variable frequency (VVVF), sinusoidal wave forms for controlling the speed of the said motor using space vector pulse width modulation (SVPWM) or sinusoidal pulse width modulation (SPWM) technique, and are mounted through mounting means to the said heat sink,
- a cooling means mounted on the shaft of the said motor to first cool the electronics of PB & CB mounted on the heat sink and thereafter cool the stator of the motor,
- an input rectifier and the filter capacitors are connected to PWM bridge inverter, an auxiliary power supply, which provides the power supply to the controller unit and the driver IC are housed in the handle of the tool.

2. A portable electric tool as claimed in claim 1 wherein the said motor is an AC motor or brushless DC motor.

3. A portable electric tool as claimed in claim 2 wherein the said AC motor is a single-phase motor or a three phase motor or a poly-phase motor

4. A portable electric tool as claimed in claim 2 wherein the said AC motor is an induction, reluctance or synchronous motor.

5. A portable electric tool as claimed in claim 2 wherein brushless DC (BLDC) motor is in two or three phases with two or three pairs of winding.

6. A portable electric tool as claimed in claim 1 wherein the PWM bridge inverter (single phase inverter) consists of at least 4 power transistors with corresponding gates in case a single-phase motor is connected at its output.

7. A portable electric tool as claimed in claims 1 & 6 wherein said software programme provides not more than four switching configurations of the said inverter bridge to produce variable voltage variable frequency (VVVF) sinusoidal voltage wave form for controlling the speed of the said single-phase motor using space vector width modulation (SVPWM) or sinusoidal pulse width modulation (SPWM) technique.

8. A portable electric tool as claimed in claim 1 wherein the PWM bridge inverter (three-phase inverter) consists of at least six power transistors with corresponding gates and the AC motor connected to the output of said PWM bridge inverter is a three-phase motor or brushless DC (BLDC) motor with three pairs of windings (three-phases).

9. A portable electric tool as claimed in claims 1 & 8 wherein the said software programme provides not more than eight switching configurations of the said inverter bridge to produce variable voltage variable frequency (VVVF) sinusoidal voltage wave form for controlling the speed of the said three phase motor using space vector width modulation (SVPWM) or sinusoidal pulse width modulation (SPWM) technique.

10. A portable electric tool as claimed in claims 2 & 6 wherein two single phase PWM bridges totaling eight power transistors are provided for BLDC motor with two pairs of winding (two-phase motor), the output of each of these two bridges is connected to the two winding pairs such that the output of second winding is delayed by 90° from the first one.

11. A portable electric tool as claimed in claims 1 & 7 wherein the said software programme manipulates switching configurations of the said inverter bridge to produce variable voltage variable frequency (VVVF) sinusoidal voltage wave form for controlling the speed of the said motor using space vector width modulation (SVPWM) or sinusoidal pulse width modulation (SPWM) technique.

12. A portable electric tool as claimed in claim 1 wherein the mounting means are the mounting screws.

13. A portable electric tool as claimed in claim 1 wherein the means for cooling is an induced draft fan.

14. A portable electric tool as claimed in claim 1 wherein a higher grade silicon steel of reduced thickness is used as core in the motor to reduce the core-losses of the said motor.

15. A portable electric tool as claimed in claim 1 wherein the ON / OFF switch of the tool is also incorporated in the handle.

16. A portable electric tool as claimed in claim 1 wherein the output shaft of the said motor is connected to the gearbox, when required.

17. A portable electric tool as claimed in claim 1 wherein the controller is a micro-controller with the associated processor, ROM, RAM and the input / output (I/O ports) having said software programme in ROM to produce timing signals through the output port to the said gates through the driver IC.

18. A portable electric tool as claimed in claim 1 wherein the said software programme includes soft-start means.

19. A portable electric tool as claimed in claim 1 wherein the said controller unit provides a multi-speed capability to the said motor, if desired.

20. A portable electric tool as claimed in claim 1 wherein the said power transistors in the PWM bridge inverter are of MOSFET (metal oxide semi-conductor field effect transistor) or IGBT (insulated gate bi-polar transistor), type to make the gate driver circuitry simple.

21. A portable electric tool as claimed in claim 1 wherein the heat sink for the power transistors and the non-drive side end cover of the motor have been integrated to achieve optimum utilization of space.

22. A portable electric tool as claimed in claim 1 wherein thermal over-load protection means is provided for the motor windings.

23. A portable electric tool as claimed in claim 1 wherein over-current protection means are provided for the said PWM bridge inverter.

24. A portable electric tool as claimed in claim 1 wherein the short code length of the programme is from 100-1000 bytes, preferably 200-400 bytes depending upon the number of speed steps required.

25. A portable electric tool as claimed in claim 1 wherein the said software programme in the micro-controller is such that it obtains the maximum utilization of the said input DC voltage to the inverter by the implementation of SVPWM technique.

26. A portable electric tool as claimed in claim 1 wherein the said software programme generates a symmetric pattern of timing signals thereby producing variable voltage variable frequency (VVVF) single phase or polyphase sinusoidal wave forms with the least harmonic content.

27. A portable electric tool as claimed in claim 1 wherein the said software program also includes means to generate dead band in the switching signals to ensure that at no point of time any 2 transistors in the same leg of PWM bridge inverter are conducting simultaneously.

28. A portable electric tool as claimed in claim 1 wherein the said software program further includes means to obtain the set speed of the said motor from the operator console

29. A portable electric tool as claimed in claim 1 wherein said auxiliary power supply means generates the 5V, 15V DC required for powering the micro-controller and the driver IC respectively.

30. A portable electric tool as claimed in claim 1 wherein the controller, driver IC and the auxiliary power supply are implemented in an ASIC.

31. A portable electric tool as claimed in claim 30 wherein the controller ASIC has means to interface with an external memory chip, if required.

32. A portable electric tool as claimed in claim 1 wherein a digital sign wave synthesizer is provided, which generates in real time, a set of single phase or polyphase wave forms as per the Space Vector Pulse Width Modulation (SVPWM) technique.

33. A portable electric tool as claimed in claim 1 wherein the controller unit and the passive components are implemented in a hybrid IC.

Patentansprüche

1. Tragbares Elektrowerkzeug, das Folgendes umfasst:

- ein Gehäuse für einen Motor,
- eine nichtantriebsseitige Endabdeckung mit einem Lager in der Mitte für den genannten Motor,
- eine Wärmesenke, die in den genannten Abdeckungen integriert oder separat darauf vorgesehen ist,
- einen PWM-Brückeninverter, bestehend aus Leistungstransistoren mit entsprechenden Gattern, wobei der Ausgang des genannten PWM-Brückeninverters mit dem genannten Motor verbunden ist,
- wobei die genannten Leistungstransistoranschlüsse mit einer Leiterplatte (PB) verbunden und an der genannten Wärmesenke montiert sind,
- wobei die Steuereinheit ein Software-Programm mit einer kurzen Codelänge hat und die Treiber-IC zum Ansteuern der genannten Gatter mit einer weiteren Leiterplatte (CB) verbunden sind,
- wobei die beiden genannten Leiterplatten (PB & CB) miteinander verbunden sind, um die zeitlichen Ablaufsequenzen zum Erzeugen der Signale zum Ein-/Ausschalten der Gatter der Leistungstransistoren des genannten PWM-Brükkeninverters zu bestimmen, um spannungsgeregelte, frequenzgestellte (VVVF) Sinuswellenformen zum Regeln der Drehzahl des genann-

ten Motors mit Hilfe von Raumvektor-Impulsbreitenmodulations- (SVPWM-) oder Sinusform-Impulsbreitenmodulations- (SPWM-) -Technik zu erzeugen, und mit Montagemitteln an der genannten Wärmesenke montiert sind,

- wobei ein Kühlmittel an der Welle des genannten Motors montiert ist, um zunächst die an der Wärmesenke montierte Elektronik von PB & CB und danach den Ständer des Motors zu kühlen,
- wobei ein Eingangsgleichrichter und die Filterkondensatoren mit dem PWM-Brückeninverter verbunden sind und eine Zusatzstromversorgung, die die Steuereinheit mit Strom versorgt, und die Treiber-IC sich im Griff des Werkzeugs befinden.

2. Tragbares Elektrowerkzeug nach Anspruch 1, wobei der genannte Motor ein Wechselstrommotor oder ein bürstenloser Gleichstrommotor ist.

3. Tragbares Elektrowerkzeug nach Anspruch 2, bei dem der genannte Wechselstrommotor ein Einphasenmotor oder ein Drehstrommotor oder ein Mehrphasenmotor ist.

4. Tragbares Elektrowerkzeug nach Anspruch 2, bei dem der genannte Wechselstrommotor ein Induktions-, Reluktanz- oder Synchronmotor ist.

5. Tragbares Elektrowerkzeug nach Anspruch 2, bei dem der bürstenlose Gleichstrom- (BLDC-) -motor in zwei oder drei Phasen mit zwei oder drei Wicklungspaaren vorliegt.

6. Tragbares Elektrowerkzeug nach Anspruch 1, bei dem der PWM-Brückeninverter (Einphaseninverter) aus wenigstens 4 Leistungstransistoren mit entsprechenden Gattern besteht, wenn ein Einphasenmotor an seinem Ausgang angeschlossen ist.

7. Tragbares Elektrowerkzeug nach Anspruch 1 & 6, bei dem das genannte Software-Programm nicht mehr als vier Schaltkonfigurationen der genannten Inverterbrücke bereitstellt, um eine spannungsgeregelte, frequenzgestellte (VVVF) Sinusspannungswellenform zum Regeln der Drehzahl des genannten Einphasenmotors mit Hilfe von Raumvektor-Breitenmodulations- (SVPWM-) oder Sinusform-Breitenmodulations-(SPWM-) -Technik zu erzeugen.

8. Tragbares Elektrowerkzeug nach Anspruch 1, bei dem der PWM-Brückeninverter (Drehstrominverter) aus wenigstens sechs Leistungstransistoren mit entsprechenden Gattern besteht und der am Ausgang des genannten PWM-Brückeninverters angeschlossene Wechselstrommotor ein Drehstrommotor oder ein bürstenloser Gleichstrom-(BLDC-) -motor mit drei Wicklungspaaren (drei Phasen) ist.

9. Tragbares Elektrowerkzeug nach Anspruch 1 & 8, bei dem das genannte Software-Programm nicht mehr als acht Schaltkonfigurationen der genannten Inverterbrücke bereitstellt, um eine spannungsgeregelte, frequenzgestellte (VVVF) Sinusspannungswellenformen zum Regeln der Drehzahl des genannten Drehstrommotors mit Raumvektor-Breitmodulations-(SVPWM-) oder Sinusform-Breitenmodulations- (SPWM-) -Technik zu erzeugen.

10. Tragbares Elektrowerkzeug nach Anspruch 2 & 6, bei dem zwei einphasige PWM-Brücken mit insgesamt acht Leistungstransistoren für einen BLDC-Motor mit zwei Wicklungspaaren (Zweiphasenmotor) vorgesehen sind, wobei der Ausgang von jeder dieser beiden Brücken so mit den beiden Wicklungspaaren verbunden ist, dass der Ausgang der zweiten Wicklung um 90° zur ersten verzögert ist.

11. Tragbares Elektrowerkzeug nach Anspruch 1 & 7, bei dem das genannte Software-Programm Schaltkonfigurationen der genannten Inverterbrücke manipuliert, um eine spannungsgeregelte, frequenzgestellte (VVVF) Sinusspannungswellenform zum Regeln der Drehzahl des genannten Motors mit Raumvektor-Breitenmodulations- (SVPWM- oder Sinusform-Breitenmodulations-(SPWM-) -Technik zu erzeugen.

12. Tragbares Elektrowerkzeug nach Anspruch 1, bei dem die Montagemittel Montageschrauben sind.

13. Tragbares Elektrowerkzeug nach Anspruch 1, bei dem das Kühlmittel ein Saugzuglüfter ist.

14. Tragbares Elektrowerkzeug nach Anspruch 1, bei dem ein Siliziumstahl höherer Güte mit reduzierter Dicke als Kern im Motor verwendet wird, um die Kernverluste des genannten Motors zu reduzieren.

15. Tragbares Elektrowerkzeug nach Anspruch 1, bei dem der Ein-/Ausschalter des Werkzeugs ebenso im Griff integriert ist.

16. Tragbares Elektrowerkzeug nach Anspruch 1, bei dem die Abtriebswelle des genannten Motors bei Bedarf mit dem Getriebe verbunden wird.

17. Tragbares Elektrowerkzeug nach Anspruch 1, bei dem die Steuerung eine Mikrosteuerung mit dem zugehörigen Prozessor, ROM, RAM, und den Ein-/Ausgangsports (E/A) mit dem genannten Software-Programm im ROM ist, um Zeitsteuersignale durch

den Ausgangsport zu den genannten Gattern durch die Treiber-IC zu erzeugen.

18. Tragbares Elektrowerkzeug nach Anspruch 1, bei dem das genannte Software-Programm Softstartmittel beinhaltet.

19. Tragbares Elektrowerkzeug nach Anspruch 1, bei dem die genannte Steuereinheit dem genannten Motor bei Bedarf die Fähigkeit für mehrere Drehzahlen gibt.

20. Tragbares Elektrowerkzeug nach Anspruch 1, bei dem die genannten Leistungstransistoren im PWM-Brückeninverter vom Typ MOSFET (Metalloxidhalbleiter-Feldeffekttransistor) oder IGBT (isolierter bipolarer Gattertransistor) sind, um die Schaltungsanordnung des Gattertreibers einfach zu machen.

21. Tragbares Elektrowerkzeug nach Anspruch 1, bei dem die Wärmesenke für die Leistungstransistoren in der nichtantriebsseitigen Endabdeckung des Motors integriert wurde, um den verfügbaren Platz optimal auszunutzen.

22. Tragbares Elektrowerkzeug nach Anspruch 1, bei dem ein thermisches Überlastschutzmittel für die Motorwicklungen vorgesehen ist.

23. Tragbares Elektrowerkzeug nach Anspruch 1, bei dem Überstromschutzmittel für den genannten PWM-Brückeninverter vorgesehen sind.

24. Tragbares Elektrowerkzeug nach Anspruch 1, bei dem die kurze Codelänge des Programms 100-1000 Byte, vorzugsweise 200-400 Byte beträgt, je nach der benötigten Zahl der Drehzahlstufen.

25. Tragbares Elektrowerkzeug nach Anspruch 1, bei dem das genannte Software-Programm in der Mikrosteuerung derart ist, dass es die maximale Ausnutzung der genannten Eingangsgleichspannung zum Inverter durch die Implementation der SVPWM-Technik erzielt.

26. Tragbares Elektrowerkzeug nach Anspruch 1, bei dem das genannte Software-Programm ein symmetrisches Muster von Zeitsteuersignalen erzeugt, um einphasige oder mehrphasige spannungsgeregelte, frequenzgestellte (VVVF) Sinuswellenformen mit dem geringsten Oberwellengehalt zu erzeugen.

27. Tragbares Elektrowerkzeug nach Anspruch 1, bei dem das genannte Software-Programm auch Mittel zum Erzeugen eines Totbandes in den Schaltsignalen beinhaltet, um zu gewährleisten, dass zu keinem Zeitpunkt zwei Transistoren im selben Schenkel des PWM-Brückeninverters gleichzeitig leiten.

28. Tragbares Elektrowerkzeug nach Anspruch 1, bei dem das genannte Software-Programm ferner ein Mittel zum Erzielen der Solldrehzahl des genannten Motors von der Bedienkonsole aus beinhaltet.

29. Tragbares Elektrowerkzeug nach Anspruch 1, bei dem das genannte Zusatzstromversorgungsmittel die 5V, 15V Gleichstrom erzeugt, die zum jeweiligen Speisen von Mikrosteuerung und Treiber-IC benötigt werden.

30. Tragbares Elektrowerkzeug nach Anspruch 1, bei dem Steuerung, Treiber-IC und Zusatzstromversorgung in einer ASIC implementiert werden.

31. Tragbares Elektrowerkzeug nach Anspruch 30, bei dem die ASIC der Steuerung Mittel für einen bedarfsabhängigen Anschluss an einen externen Speicherchip hat.

32. Tragbares Elektrowerkzeug nach Anspruch 1, bei dem ein Digitalzeichen-Wellensynthesizer vorgesehen ist, der in Echtzeit einen Satz von Einphasen- oder Mehrphasen-Wellenformen gemäß der Raumvektor-Impulsbreitenmodulations- (SVPWM) Technik erzeugt.

33. Tragbares Elektrowerkzeug nach Anspruch 1, bei dem die Steuereinheit und die passiven Komponenten in einer Hybrid-IC implementiert sind.

Revendications

1. Outil électrique portatif comprenant :

- un carter pour un moteur,
- un couvercle d'extrémité de non-d'entraînement ayant en son centre un palier pour ledit moteur,
- un dissipateur thermique fourni soit intégralement, soit séparément sur lesdits couvercles,
- un inverseur à pont PWM consistant en transistors de puissance à grilles correspondantes, la sortie dudit inverseur à pont PWM est connectée audit moteur,
- les bornes desdits transistors de puissance sont connectées à une carte à circuit imprimé (PB) et sont montées sur ledit dissipateur thermique,
- l'unité de contrôleur ayant un programme logiciel d'une courte longueur de code et le CI d'attaque pour attaquer lesdites grilles sont connectées à une autre carte à circuit imprimé

(CB),

- lesdites deux cartes (PB et CB) sont interconnectées pour déterminer les séquences de cadencement pour générer les signaux servant à rendre passantes/bloquantes les grilles des transistors de puissance dudit inverseur à pont PWM de façon à produire des formes d'onde sinusoïdales de tension variable fréquence variable (VVVF) pour commander la vitesse dudit moteur en utilisant une technique de modulation de largeur d'impulsion de vecteur spatial (SVPWM) ou de modulation de largeur d'impulsion sinusoïdale (SPWM), et sont montées par le biais de moyens de montage audit dissipateur thermique,
- un moyen de refroidissement monté sur l'arbre dudit moteur pour refroidir tout d'abord les circuits électroniques des PB et CB montées sur le dissipateur thermique et refroidir ensuite le stator du moteur,
- un redresseur d'entrée et les condensateurs de filtrage sont connectés à l'inverseur à pont PWM, une alimentation électrique auxiliaire, laquelle fournit l'alimentation électrique à l'unité de contrôleur et au CI d'attaque sont logés dans le manche de l'outil.

2. Outil électrique portatif selon la revendication 1, dans lequel ledit moteur est un moteur C.A. ou un moteur C.C. sans balais.

3. Outil électrique portatif selon la revendication 2, dans lequel ledit moteur C.A. est un moteur monophasé ou un moteur triphasé ou un moteur polyphasé.

4. Outil électrique portatif selon la revendication 2, dans lequel ledit moteur C.A est un moteur à induction, réluctance ou synchrone.

5. Outil électrique portatif selon la revendication 2, dans lequel le moteur C.C. sans balais (BLDC) est à deux ou trois phases avec deux ou trois paires d'enroulements.

6. Outil électrique portatif selon la revendication 1, dans lequel l'inverseur à pont PWM (inverseur monophasé) consiste en au moins 4 transistors de puissance à grilles correspondantes quand un moteur monophasé est connecté à sa sortie.

7. Outil électrique portatif selon les revendications 1 et 6, dans lequel ledit programme logiciel fournit pas plus de quatre configurations de commutation dudit pont inverseur afin de produire une forme d'onde de tension sinusoïdale à tension variable fréquence variable (VVVF) pour commander la vitesse dudit moteur monophasé en utilisant une technique de modulation de largeur de vecteur spatial (SVPWM) ou de modulation de largeur d'impulsion sinusoïdale (SPWM).

8. Outil électrique portatif selon la revendication 1, dans lequel l'inverseur à pont PWM (inverseur triphasé) consiste en au moins six transistors de puissance à grilles correspondante et le moteur C.A. connecté à la sortie dudit inverseur à pont PWM est un moteur triphasé ou un moteur C.C. sans balais (BLDC) à trois paires d'enroulements (trois phases).

9. Outil électrique portatif selon les revendications 1 et 8, dans lequel ledit programme logiciel fournit pas plus de huit configurations de commutation dudit pont inverseur afin de produire une forme d'onde de tension sinusoïdale à tension variable fréquence variable (VVVF) pour commander la vitesse dudit moteur triphasé en utilisant une technique de modulation de largeur de vecteur spatial (SVPWM) ou de modulation de largeur d'impulsion sinusoïdale (SPWM).

10. Outil électrique portatif selon les revendications 2 et 6, dans lequel deux ponts PWM monophasés totalisant huit transistors de puissance sont fournis pour le moteur BLDC à deux paires d'enroulements (moteur biphasé), la sortie de chacun de ces deux ponts est connectée aux deux paires d'enroulements de telle sorte que la sortie dudit deuxième enroulement soit retardée de 90° par rapport à celle du premier.

11. Outil électrique portatif selon les revendications 1 et 7, dans lequel ledit programme logiciel manipule les configurations de commutation dudit pont inverseur afin de produire une forme d'onde de tension sinusoïdale à tension variable fréquence variable (VVVF) pour commander la vitesse dudit moteur en utilisant une technique de modulation de largeur de vecteur spatial (SVPWM) ou de modulation de largeur d'impulsion sinusoïdale (SPWM).

12. Outil électrique portatif selon la revendication 1, dans lequel les moyens de montage sont des vis de montage.

13. Outil électrique portatif selon la revendication 1, dans lequel le moyen de refroidissement est un ventilateur à tirage par aspiration.

14. Outil électrique portatif selon la revendication 1, dans lequel un acier au silicium de qualité supérieure d'une épaisseur réduite est utilisé comme noyau du moteur afin de réduire les pertes de noyau dudit moteur.

15. Outil électrique portatif selon la revendication 1, dans lequel la mise sous/hors tension de l'outil est aussi incorporée dans le manche.

16. Outil électrique portatif selon la revendication 1, dans lequel l'arbre de sortie dudit moteur est connecté à la boîte d'engrenages, selon les besoins.

17. Outil électrique portatif selon la revendication 1, dans lequel le contrôleur est un micro-contrôleur avec les processeur, ROM, RAM et entrée/sortie (ports E/S) associés, ledit programme logiciel se trouvant dans la ROM pour produire des signaux de cadencement par le biais du port de sortie auxdites grilles par le biais du CI d'attaque.

18. Outil électrique portatif selon la revendication 1, dans lequel ledit programme logiciel comporte un moyen de mise sous tension sans appel de courant.

19. Outil électrique portatif selon la revendication 1, dans lequel ladite unité de contrôleur fournit une capacité de vitesses multiples audit moteur, si cela est désiré.

20. Outil électrique portatif selon la revendication 1, dans lequel lesdits transistors de puissance dans l'inverseur à pont PWM sont du type MOSFET (transistor à effet de champ à semiconducteur métal-oxyde) ou IGBT (transistor bipolaire à grille isolée) afin de simplifier les circuits d'attaque de grilles.

21. Outil électrique portatif selon la revendication 1, dans lequel le dissipateur thermique des transistors de puissance et le couvercle d'extrémité du côté de non-entraînement ont été intégrés pour utiliser l'espace de façon optimale.

22. Outil électrique portatif selon la revendication 1, dans lequel un moyen de protection de surcharge thermique est fourni pour les enroulements du moteur.

23. Outil électrique portatif selon la revendication 1, dans lequel des moyens de protection de surintensité sont fournis pour ledit inverseur à pont PWM.

24. Outil électrique portatif selon la revendication 1, dans lequel la courte longueur de code du programme est de 100 à 1000 octets, de préférence de 200 à 400 octets en fonction du nombre de pas de vitesses requis.

25. Outil électrique portatif selon la revendication 1, dans lequel ledit programme logiciel dans le micro-contrôleur est tel qu'il procure l'utilisation maximale de ladite tension C.C. D'entrée allant à l'inverseur par la mise en oeuvre de la technique SVPWM.

26. Outil électrique portatif selon la revendication 1, dans lequel ledit programme logiciel génère une configuration symétrique des signaux de cadencement produisant ainsi des formes d'onde sinusoïdales monophasées ou polyphasées à tension variable fréquence variable (VVVF) avec le plus petit contenu harmonique.

27. Outil électrique portatif selon la revendication 1, dans lequel ledit programme logiciel comporte aussi un moyen pour générer une bande morte dans les signaux de commutation pour garantir qu'à aucun moment 2 transistors quelconques dans la même branche de l'inverseur à pont PWM conduisent simultanément.

28. Outil électrique portatif selon la revendication 1, dans lequel ledit programme logiciel comporte en outre un moyen pour obtenir la vitesse de fonctionnement dudit moteur à partir de la console d'opérateur.

29. Outil électrique portatif selon la revendication 1, dans lequel ledit moyen d'alimentation électrique auxiliaire génère les 5V, 15V C.C requis pour alimenter respectivement le micro-contrôleur et le CI d'attaque.

30. Outil électrique portatif selon la revendication 1, dans lequel le contrôleur, le CI d'attaque et l'alimentation électrique auxiliaire sont mis en oeuvre dans un ASIC.

31. Outil électrique portatif selon la revendication 30, dans lequel l'ASIC de contrôleur a un moyen pour s'interfacer avec une puce de mémoire externe, si on le désire.

32. Outil électrique portatif selon la revendication 1, dans lequel un synthétiseur numérique d'ondes sinusoïdales est fourni, lequel génère en temps réel un ensemble de formes d'onde monophasées ou polyphasées selon la technique de Modulation de Largeur d'Impulsion de Vecteur Spatial (SVPWM).

33. Outil électrique portatif selon la revendication 1, dans lequel l'unité de contrôleur et les composants passifs sont mis en oeuvre dans un CI hybride.

FIG 1 — ANGLE GRINDER

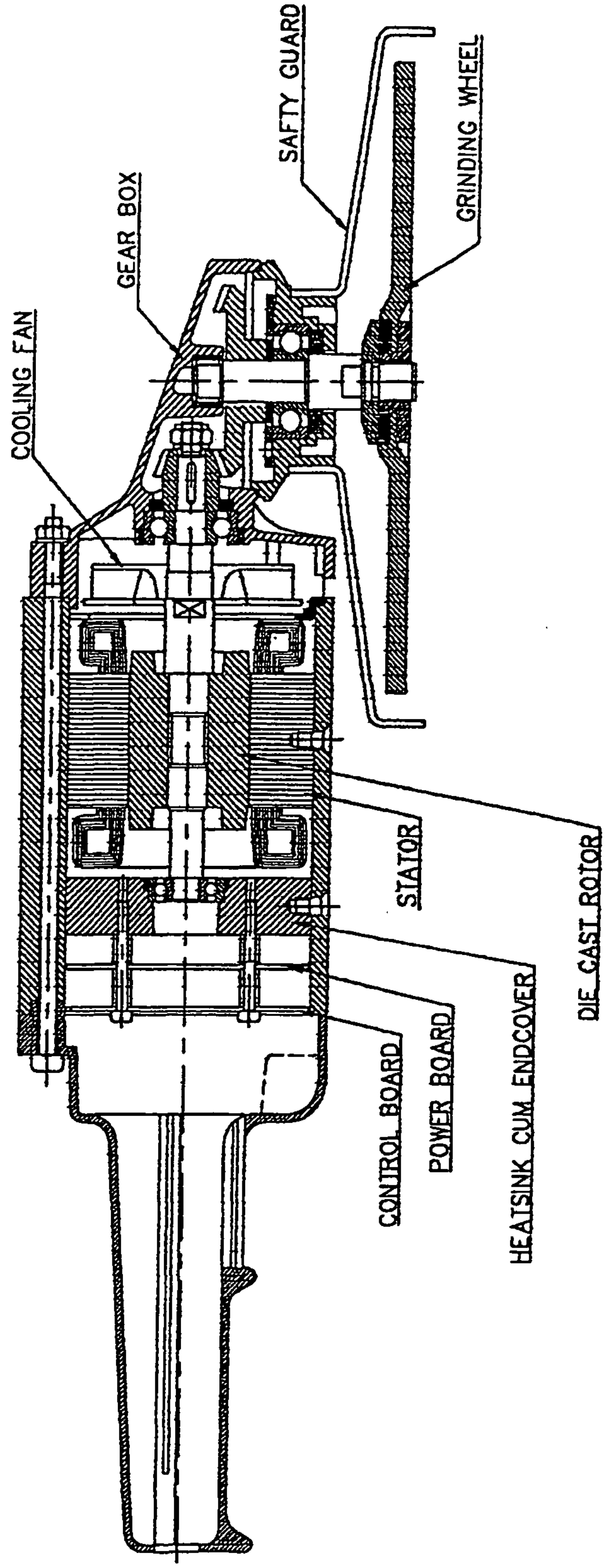


FIG. 2 – DRILL

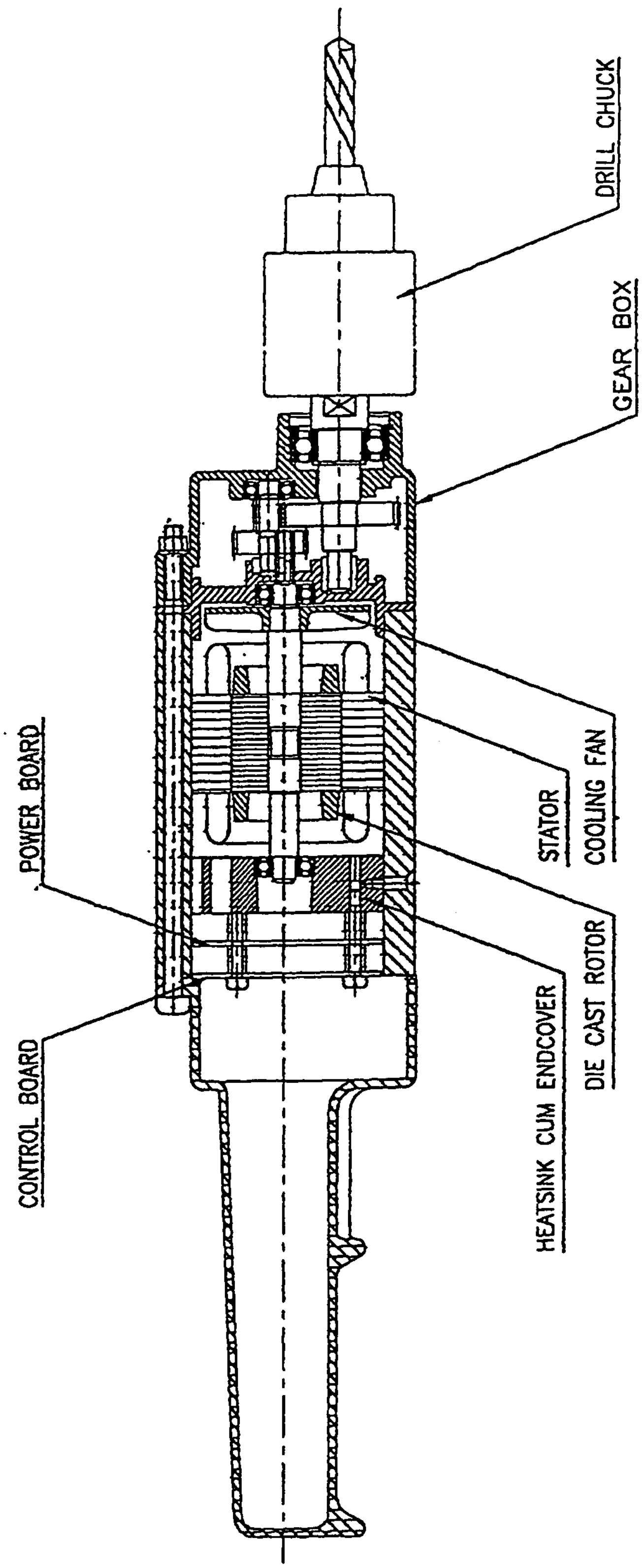
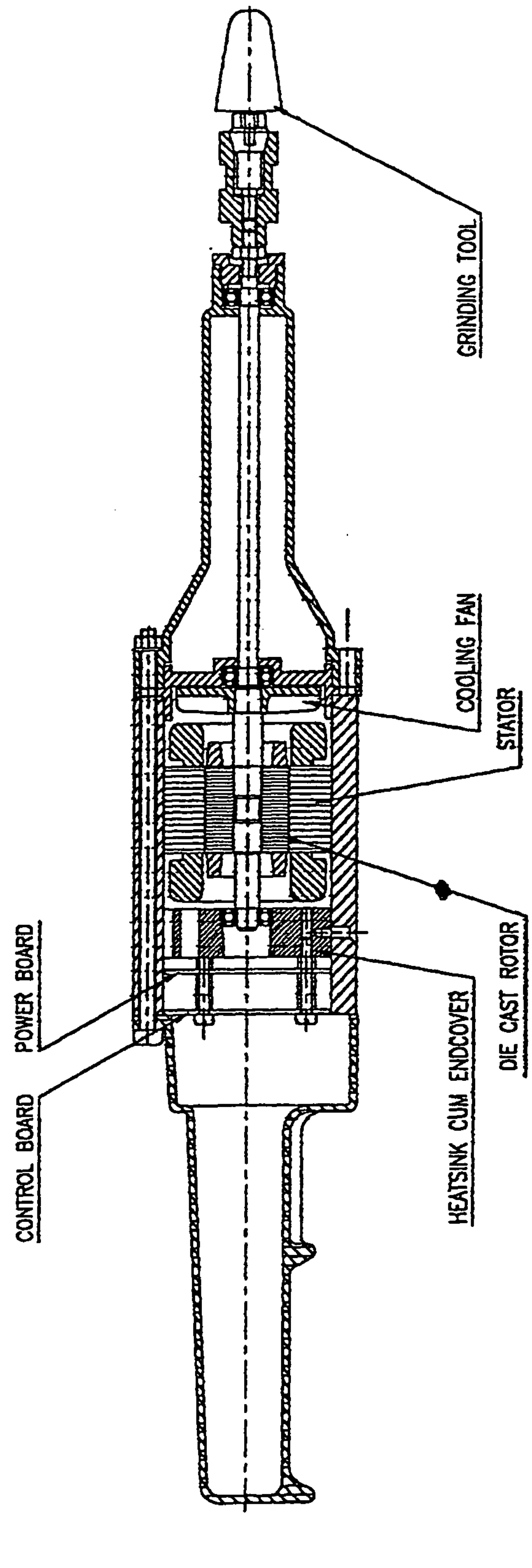

DRILL CHUCK
GEAR BOX
COOLING FAN
STATOR
DIE CAST ROTOR
HEATSINK CUM ENDCOVER
POWER BOARD
CONTROL BOARD

FIG. 3 — DIE POLISHER



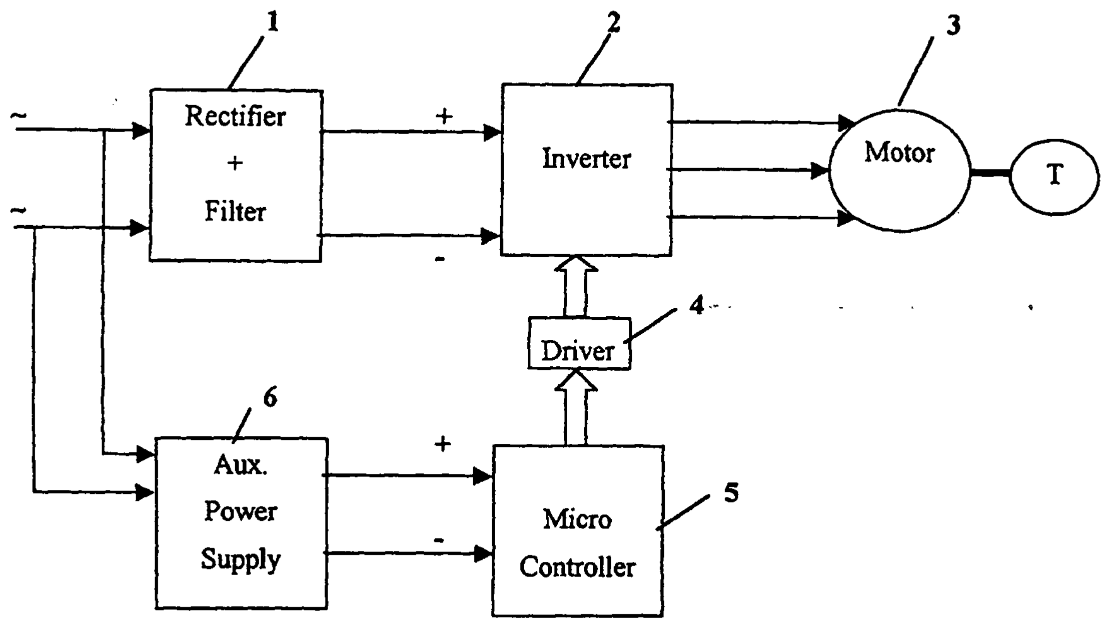


Fig. 4 – General Block Diagram

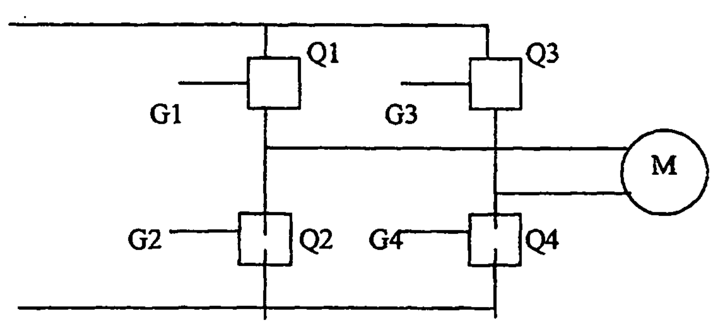


Fig. 5a: (Single Phase Bridge)

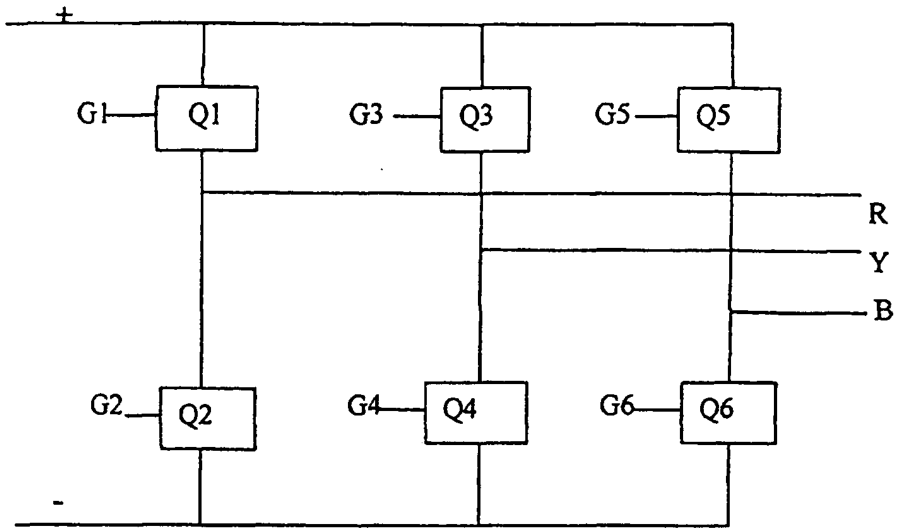


Fig. 5b – Three Phase Inverter

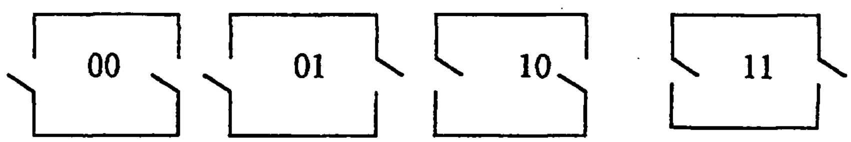


Fig. 6a: (Switching Configuration of Single Phase Bridge)

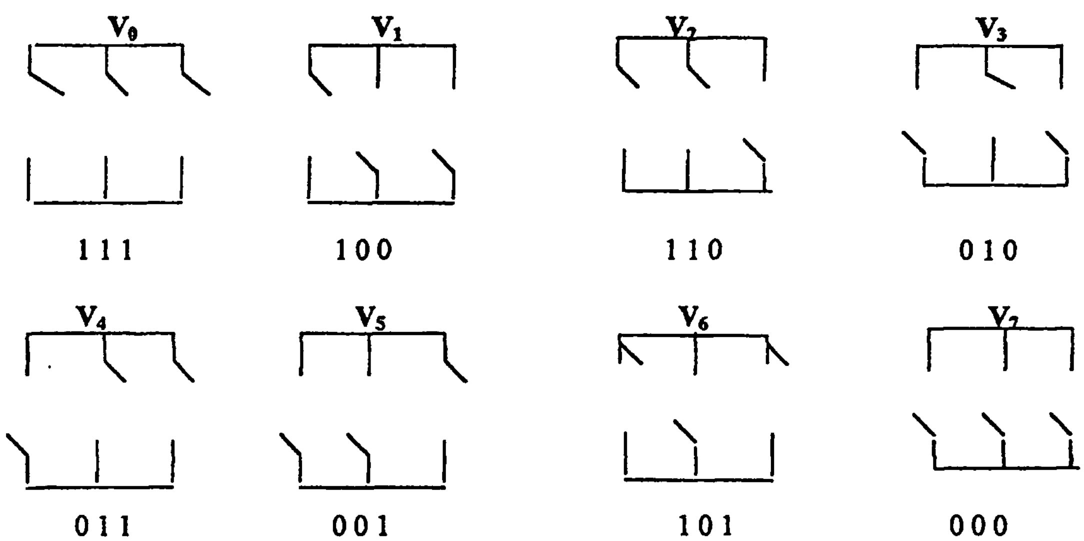


FIG. 6b – Switching Configuration Of Pwm 3 Phase Inverter

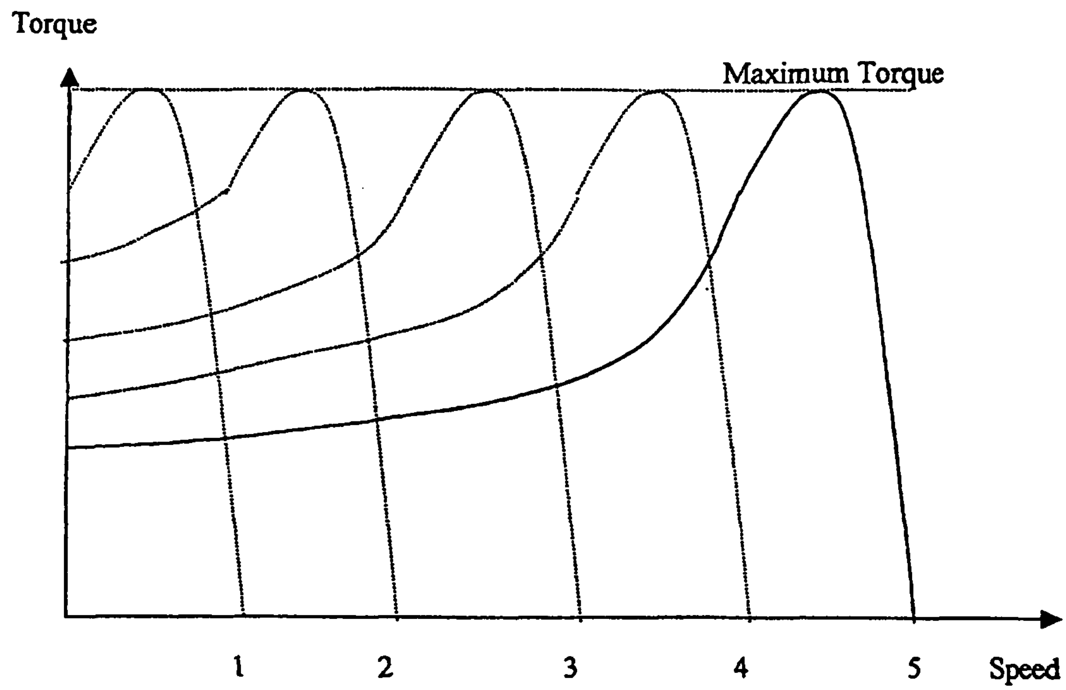


Fig. 7 – Torque Vs Speed during Soft-Start

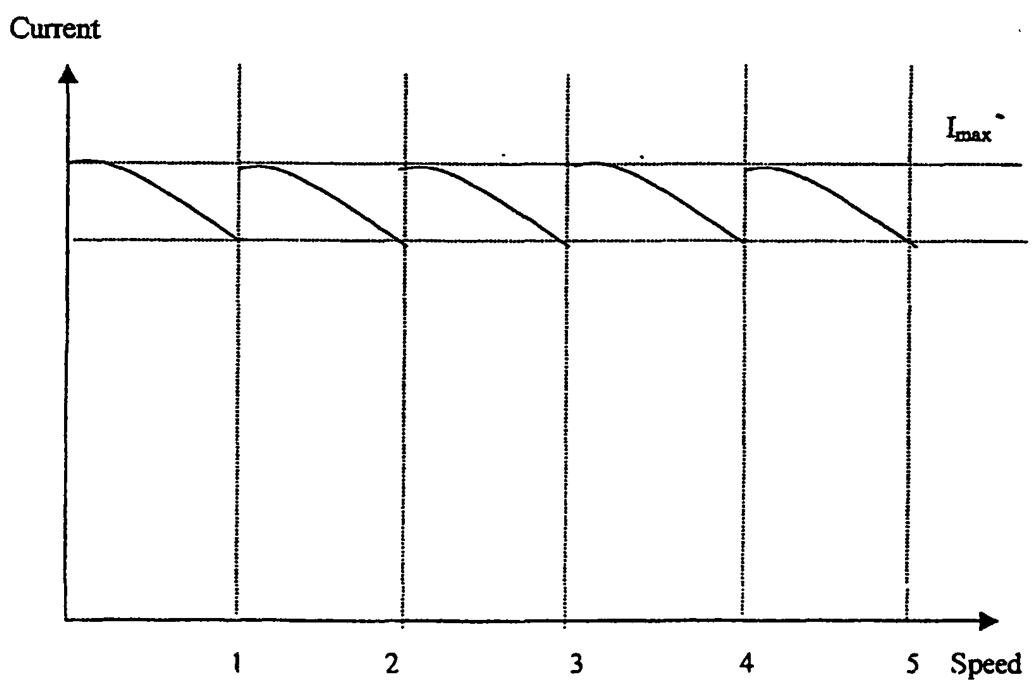
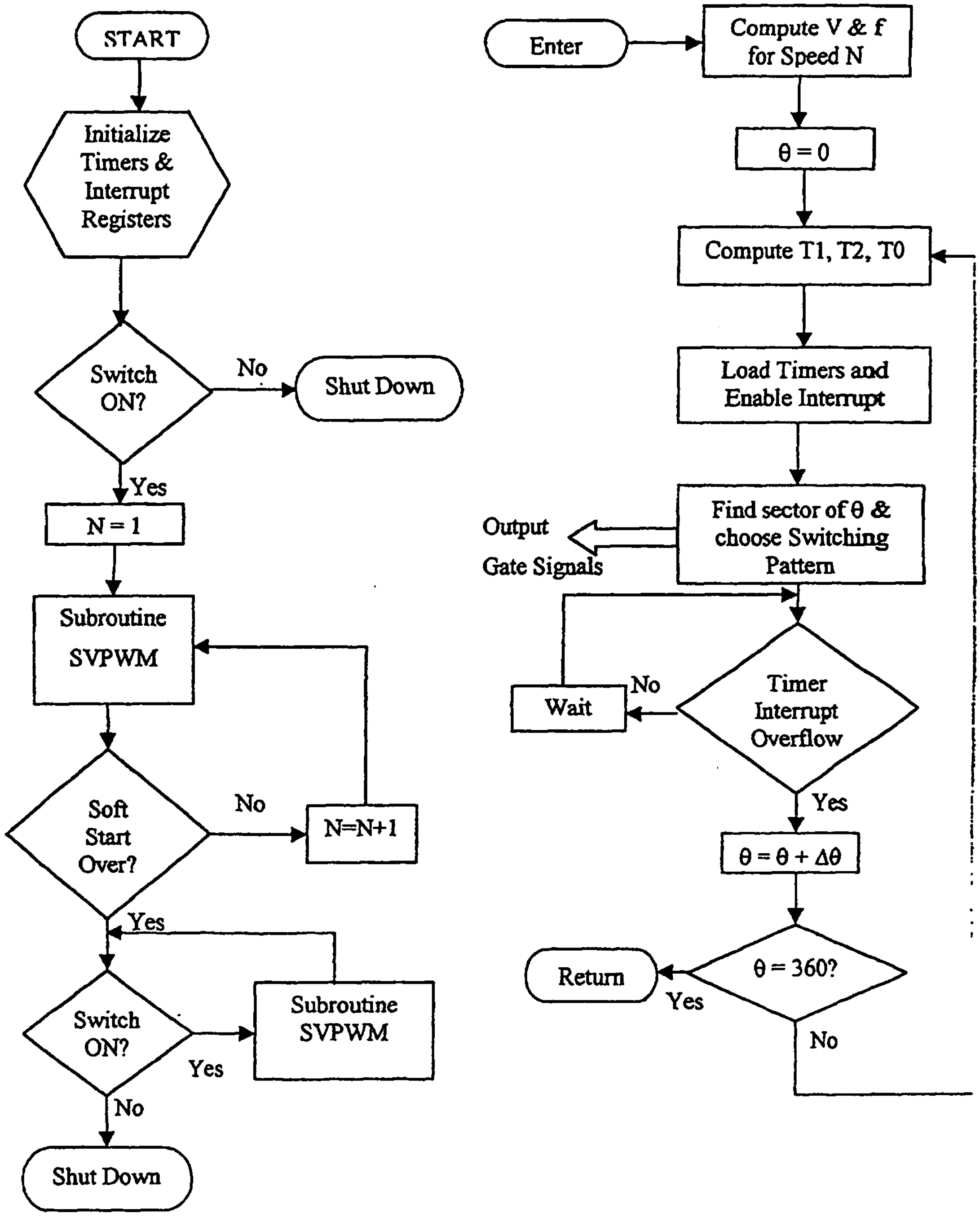


Fig. 8 – Current Vs Speed during Soft-Start

Fig. 9 – Flow Chart

Subroutine SVPWM



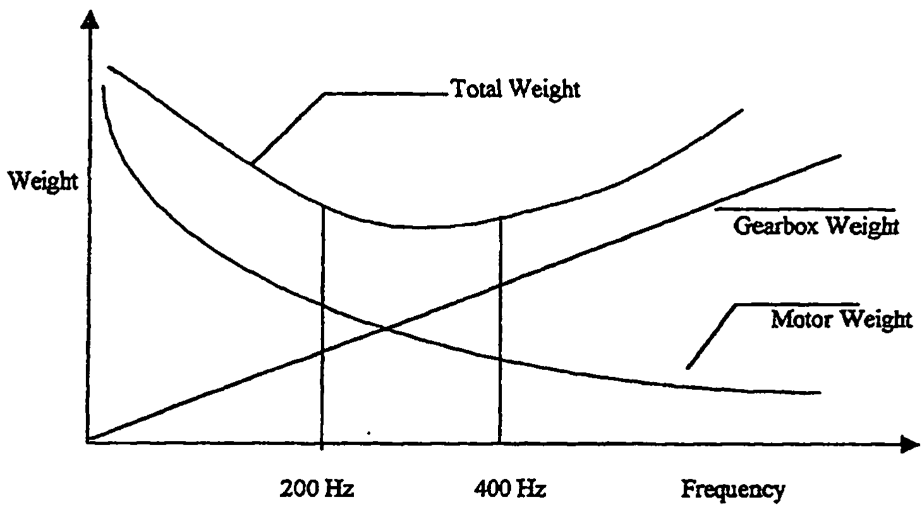


Fig. 10 – Weight Vs Frequency of A Portable Tool

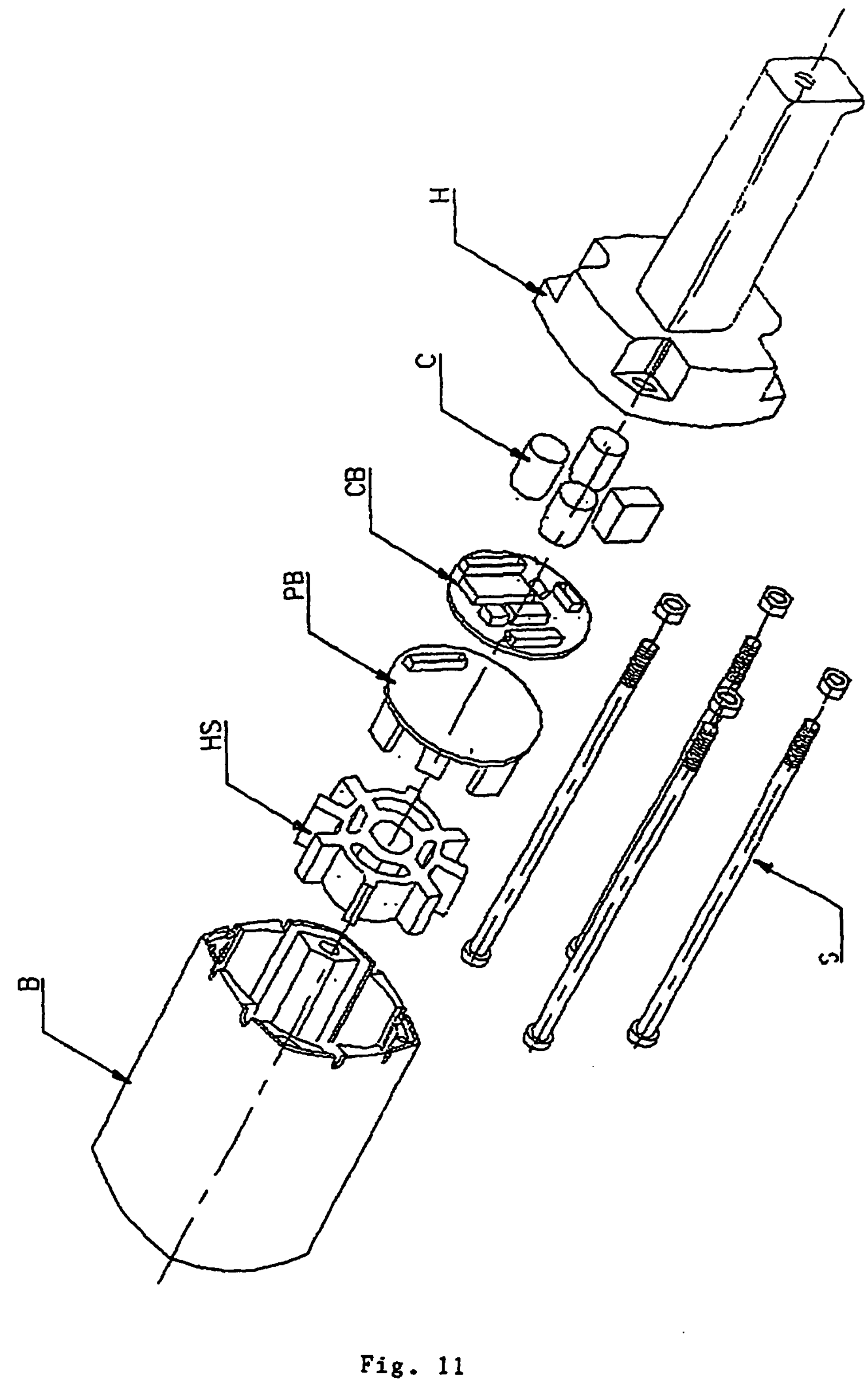


Fig. 11